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# Curriculum Materials as a Professional Development Tool: How a Mathematics Textbook Affected Two Teachers' Learning

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## Abstract

This study reports on 2 upper-elementary teachers' learning through their use of potentially educative mathematics curriculum materials without additional professional development. 41 observations of the teachers' mathematics lessons and 28 interviews of the teachers were collected from October to May of an academic year. The case study analyses indicated that curriculum materials can be an effective professional development tool, but perhaps not for all teachers. 1 teacher's instructional focus and rationale for instructional practices remained stable throughout the school year, whereas the other's changed dramatically. The cases illustrated the teachers' dynamic and divergent nature of opportunities to learn through reading materials and enacting lessons. Findings also indicated that consideration of the interaction between beliefs integral to teachers' identity and those that are targets for change may illuminate responses to potentially educative curriculum materials.

Teacher learning is widely acknowledged as critical to educational reforms. Although textbooks and other curriculum materials are ubiquitous in American schools (Woodward & Elliot, 1990), researchers are just beginning to investigate the contributions of curriculum materials designed to support teacher learning (Remillard, 2000; Schneider & Krajcik, 2000). The purpose of this article is to report a study of two elementary teachers' use of and learning from curriculum materials designed to support teacher learning in addition to providing a sequence of mathematics lessons for students.

## Supporting Teacher Learning

Research on teacher learning has suggested that effective professional development in-

tegrates several crucial elements. First, support for teacher learning is more effective when it is linked closely to teachers' classroom context (Borko & Putnam, 1996; Cohen & Hill, 1998; Kagan, 1992; Little, 1993; Smylie, 1989). Second, because learning develops in iterative cycles over extended periods (Blumenfeld, Krajcik, Marx, & Soloway, 1994; Edwards, 1996; Richardson, 1996), effective support is ongoing and long term (Brickhouse & Bodner, 1992; Briscoe, 1991; Marx, Freeman, Krajcik, & Blumenfeld, 1998; Schifter & Fosnot, 1993). Third, teachers need opportunities to build new beliefs and knowledge about teaching, learning, and subject matter (Borko & Putnam, 1996; Smylie, 1996). In mathematics, teachers are asked to enact approaches that often differ greatly from their own experiences of mathematics instruction (Schifter & Fosnot, 1993) and that require a deeper knowledge of mathematics than many teachers have (Ball, 1991; Leinhardt & Smith, 1985; Stein, Baxter, & Leinhardt, 1990). Although teachers' knowledge and beliefs are targets of change, they also influence change by serving as a filter through which teachers interpret new information, including curriculum content and reform recommendations (Borko & Putnam, 1996; Cohen & Ball, 1990; Wilson, 1990).

### **The Educative Potential of Curriculum Materials**

Curriculum materials could offer each of the elements of effective professional development described above (Ball & Cohen, 1996). These materials are an integral part of teachers' daily work and are intimately connected to the enactment of instruction. In addition, they are well situated to offer ongoing support for pedagogy and subject-matter content throughout an entire school year. Finally, as teachers try instructional practices in their classrooms, they may develop new beliefs and understandings (Blumenfeld et al., 1994; Guskey, 1988; Remil-

lard, 2000). In the United States, curriculum developers and researchers are beginning to consider the potential of curriculum materials as a vehicle for teacher learning about subject matter as well as instruction (Ball & Cohen, 1996; Gill & Pike, 1995; Lloyd & Frykholm, 2000; Mokros, Russell, & Economopoulos, 1995; Remillard, 1999, 2000; Schneider & Krajcik, 2000).

In contrast, curriculum materials in Japan and China are commonly designed with significant content for teachers. Japanese and Chinese teachers regularly turn to their mathematics curriculum materials for in-depth discussions of mathematics content, pedagogy, student thinking, and the connections between mathematical ideas within and across school years (Gill & Pike, 1995; Ma, 1999).

Despite the educative potential of curriculum materials, U.S. teachers' perception and use of curriculum materials suggest that such materials may not be effective without additional professional development. Preservice teachers may receive minimal guidance on how to use textbooks and contradictory messages about the value of using textbooks for planning and instruction (Ball & Feiman-Nemser, 1988). Practicing teachers do not readily think of themselves as learning from textbooks and teachers' guides (Russell et al., 1995). Furthermore, teachers vary greatly in their acceptance of or resistance to new curriculum materials (Lambdin & Preston, 1995; Remillard & Bryans, 2000), use of suggested topics and activities (Barr, 1988; Barr & Sadow, 1989; Durkin, 1984; Freeman & Porter, 1989; Stodolsky, 1988), and engagement with materials over time (Heaton, 1994; Peterson, 1990). In short, teachers may enact lessons in very different ways than how curriculum developers or educational reformers intended (Ball, 1990; Cohen, 1990; Peterson, 1990; Weimers, 1990; Wilson, 1990). This great variation in curriculum use can affect the opportunities teachers have to learn through curriculum materials.

## **Influences on the Use of Curriculum Materials**

Teachers' use of curriculum materials and response to professional development may be influenced by several factors, including the context in which teachers work (e.g. Prawat, 1992; Sosniak & Stodolsky, 1996; Stodolsky & Grossman, 1995) and their beliefs and knowledge. Students form part of the context in which teachers work (Barr, 1988; DiGisi & Willett, 1995; Prawat & Jennings, 1997). Teachers, for example, decide whether or not to alter their teaching practice in light of students' responses to instruction and the perceived needs of their students (Knapp & Peterson, 1995; Marx & Collopy, 1995; Richardson, 1990).

Teachers' beliefs and knowledge about subject matter, pedagogy, and learners may influence teachers' responses to curriculum materials including how they use materials and what they learn from them (Blumenfeld et al., 1994; Cohen & Ball, 1990; Heaton, 1994; Lloyd & Wilson, 1998; Putnam, Heaton, Prawat, & Remillard, 1992; Sosniak & Stodolsky, 1996; Stodolsky, 1988). In addition, motivational beliefs mediate whether and what learning occurs (Pintrich, Marx, & Boyle, 1993). Thus, teachers' goals, interests, values, and expectations of curriculum materials may influence their use of and learning from materials. Responses to professional development may also be influenced by teachers' beliefs about themselves including subject-matter efficacy and teaching self-efficacy. Smith (1996) suggested that reform-oriented mathematics may undermine the foundation of many teachers' mathematical and pedagogical self-efficacy because it challenges common conceptions of mathematics and mathematical pedagogy.

Researchers have noted that teachers hold some beliefs, particularly those formed through their own experiences as students, more tenaciously and that these beliefs may have a greater influence on teachers' perceptions and decisions (Lortie, 1975; Nespor, 1987; Pajaras, 1992). In addition, beliefs are

interconnected (Pajaras, 1992). A teacher's identity is the constellation of interconnected beliefs and knowledge about subject matter, teaching, and learning as well as personal self-efficacy and orientation toward work and change (Drake, Spillane, & Hufferd-Ackles, 2001; Spillane, 2000). Identity as a teacher and a learner contributes to a teacher's construction of opportunities to learn about reform-oriented instruction (Drake et al., 2001; Spillane, 2000). For example, in Spillane's (2000) case study of Ms. Adams, the convergence of the teacher's low mathematical self-efficacy with concerns about her students' moral development was central to her minimal engagement with resources related to reform efforts in mathematics.

## **What Is Not Known about Educative Curriculum Materials**

Currently, researchers do not know whether and what teachers learn through the use of curriculum materials written to support teacher learning without additional and ongoing professional development. The purpose of this study was to report on two elementary teachers' learning through their use of mathematics curriculum materials designed to support teacher learning about math and how to teach it. Specifically, in this study, I defined learning as changes in the teachers' beliefs related to teaching and learning mathematics and in their instructional practices relative to those promoted by the curriculum materials. Although feedback from others can play an important role in promoting reflection on and inquiry into practice (Fenstermacher & Richardson, 1993; Schon, 1983), neither teacher in this study received substantive feedback or guidance on her use or enactment of the curriculum materials. Clearly, this solo model of enacting new curriculum materials is far from ideal. However, it allowed a close look at how use of the materials contributed to the teachers' learning. It also reflects the reality of how new curric-

ulum materials are often introduced in schools.

## Method

### Participants

The participants in this study were two veteran upper-elementary teachers, Ms. Clark and Ms. Ross. (All names are pseudonyms.) Ms. Clark, a fifth-grade teacher, had taught for 26 years. Ms. Ross, a fourth-grade teacher, had taught a total of 11 years: 2 years directly after college, then, following a 20-year absence from teaching, the 9 years prior to this study. The teachers taught in kindergarten through fifth-grade schools in the same mainly blue-collar, mid-size city in the Midwest. Both teachers represented their schools on the district's mathematics committee. In Ms. Ross's school of 300 students, 62% received free or reduced-price lunch. In Ms. Clark's school of 420 students, 57% received free or reduced-price lunch. Ms. Ross described her 28 students as nearly all below grade level in mathematics and coming from homes with few resources to support them. In October she identified only one child who was good at mathematics. Ms. Clark described her students as below average in mathematics with families that varied in the amount of material and academic support they provided to their children.

### Curriculum Materials

*Investigations in Number, Data, and Space* (Technical Education Research Center [TERC], 1995–1996) is a kindergarten through fifth-grade mathematics curriculum developed by TERC under a grant from the National Science Foundation. *Investigations* involves an instructional approach that stresses invention of problem-solving strategies, exploration of mathematical relations, and discussion of mathematical ideas. The materials consistently advocate involving all students in investigating problem situations and communicating their mathematical ideas verbally and in writing. The curriculum materials de-emphasize

rote memorization of basic facts and definitions of mathematical vocabulary, and they do not provide for the teaching of standard problem-solving algorithms. This contrasted with the Addison-Wesley curriculum's direct instruction approach and emphasis on standard algorithms. The teachers had used this curriculum previously.

In addition, the *Investigations* materials seek to be educative by supporting teacher as well as student learning. Each *Investigations* unit is housed in a separate teacher book, and each book begins with the same introduction to the materials. Three types of sections designed to support teacher learning are found in every unit. Near the beginning of each unit a section titled "About the Mathematics in This Unit" provides a one- or two-page summary of the mathematical content in the unit. These sections are presented as "particularly valuable to teachers who are accustomed to a traditional textbook-based curriculum" (TERC, 1995–1996, p. 6). Following this section is a detailed description of the activities for students. Directions for lessons provide teachers with word-for-word suggestions on what to say and which questions to ask. "Teacher notes" and "dialogue boxes" are located after the instructional activity or activities that they support. The teacher notes, which contain information about mathematical content, representations, and pedagogy, were written in response to teachers' questions during field tests of the curriculum. Dialogue boxes contain one- to two-page samples of dialogues illustrating classroom discussions during instructional activities. Unlike the other teacher content sections, dialogue boxes are written in a scriptlike format and preceded by a sentence or two relating them to the previous instructional activity. The introduction to each unit indicates that the dialogues are meant to support teacher reflection. The dialogues "offer good clues to how your students may develop and express their approaches and strategies, helping you to

prepare for your own class discussions” (TERC, 1995–1996, p. 6). The dialogue boxes rarely identify the pedagogical or mathematical issues they are meant to illustrate, nor is guidance offered on how to extract or interpret relevant information from them. The use of the dialogues as a class activity with students is neither stated nor implied in the directions.

The materials Ms. Clark and Ms. Ross used were meant for different grade levels. However, the content for teachers, the overall approach to mathematics instruction, and the structure of lessons were comparable. (A complete analysis of the curriculum materials’ content for teachers and the instructional approach is available from the author.) As described, the materials each teacher read contained information about mathematical content and about students’ typical ideas, problem-solving strategies, errors, and difficulties. For example, the units the two teachers used had similar and sometimes identical teacher notes on modifying *Investigations’s* instructional activities, introducing mathematical vocabulary, using standard notation, and assessing students’ understanding of mathematical ideas, processes, and relations. Lessons at both grade levels began with directions for the teacher to introduce one or a few problems briefly, followed by students collaborating with peers and using a range of materials to develop solutions to the problems. The curriculum does not have individual student books. As needed, students use problem-solving and record-keeping worksheets copied from blackline masters in the teacher’s book. Lessons typically ended with discussions of problem-solving strategies, observations, and solutions.

### Data Collection

I attended the same 2-day introduction to the *Investigations* materials as the two teachers in this study. Because the teachers participating in the study had not yet been identified, my field notes focused on the information and activities the presenter high-

lighted. These data served as background for this study.

I collected two types of data in this study: observations of mathematics lessons as well as formal and informal interviews of teachers. I used audiotapes and extensive raw field notes or “jottings” (Emerson, Fretz, & Shaw, 1995) of each observation to write detailed field notes. I observed 18 of Ms. Clark’s mathematics lessons, which ranged from 35 to 60 minutes (average 48.3 minutes), for a total of 869 minutes. I observed 22 of Ms. Ross’s mathematics lessons for a total of 1,139 minutes. Her lessons ranged from 20 to 66 minutes (average 51.7 minutes). Extended formal interviews probed teachers’ beliefs and knowledge about mathematics, mathematics teaching, learners and learning, self-efficacy, and curriculum use. Many of the interview questions were adapted from an instrument that Kennedy, Ball, and McDiarmid (1993) developed. Each formal interview was audiotaped. Informal interviews frequently took place after observations of lessons had been conducted and focused on teachers’ reflections on the lessons just taught, the curriculum materials, students, and changes teachers saw in their own teaching and thinking. I wrote detailed notes during or just after each informal interview. The complete set of data consisted of 41 observations, four formal interviews, and 24 informal interviews. All data were transcribed into QSR NUD\*IST (Qualitative Solutions and Research Pty. Ltd., 1997), a qualitative data analysis software program.

Data were collected in three stages. The first stage focused on background and baseline data on teachers’ beliefs and knowledge and initial use of the curriculum. This stage began with an extended formal interview in October followed by seven classroom observations of Ms. Ross’s lessons and eight lessons Ms. Clark taught during late fall. The second stage consisted of 6 days of observations of each teacher in sets of 2 consecutive days about a month apart. These observations and informal interviews

with the teachers enabled me to investigate decisions about curriculum use and changes in beliefs and practices during the year. The third stage of data collection took place in the final weeks of the school year and consisted of 2 weeks of consecutive classroom observations followed by a final interview. The purpose of the final stage was to collect data on teachers' reflections, use of the curriculum, and beliefs, knowledge, and instructional practice toward the end of the year.

### Data Analysis

Two types of data analysis were conducted interactively using the interview and observational data: a thematic analysis and a segment analysis. An analysis of the content and pedagogical design for teacher learning offered by the *Investigations* curriculum materials also informed data analysis. Together, these three types of analysis allowed triangulation of the data and a more complete account (Maxwell, 1996).

**Thematic analysis.** The thematic analysis of the interviews and field notes explored the stability, changes, and relations among teachers' beliefs about mathematics, students, pedagogy, curriculum, and themselves as learners and teachers. I drew on the work of Ball (1990, 1991), Grossman (1990), and Shulman (1986, 1987) in developing coding categories. Categories of codes were refined, collapsed, discarded, and augmented as coding proceeded until eight broad coding categories were developed: mathematics, purposes, students, curriculum, instruction, teacher background, context, and beliefs about self.

After I had coded all documents (i.e., transcripts, field notes, and curriculum) using the eight broad codes, I used QSR NUD\*IST's report function to check the accuracy of the coding. As necessary, corrections to coding were made and a new set of reports was created. Next, I developed subcategories of codes to achieve a fuller description of each teacher's thinking across

the school year and to compare the teachers. I used several methods to aid the development of subcategories, including noting recurring patterns and themes in margins, memos attached to text units, conceptually ordered matrix displays (Miles & Huberman, 1994), and hierarchical displays of the coding categories and subcategories. Finally, I examined the content of each coding category to develop characterizations of each teacher's beliefs and knowledge including changes across the school year. Because curriculum developers and teachers may hold different meanings for the same terms (Olson, 1981), I noted how teachers used terms such as concept, understanding, and proof. I also developed cognitive maps to visually represent each teacher's conceptions of mathematics instruction and the relations between teachers' beliefs and knowledge within and across coding categories. Preliminary characterizations were checked against the interview and observational data and revised as needed. I reread interviews to make sure I had not altered the meanings of quotes by taking them out of context. I also compared characterizations of and changes in the teachers' beliefs and knowledge about mathematics, the purposes of mathematics instruction, students, curriculum, and instruction to the stances advocated in the *Investigations* curriculum materials.

The three stages of data collection allowed continual rechecking of my interpretations with the teachers. During informal interviews throughout the school year, I shared my ongoing analysis with the teachers and asked for feedback. I checked the meaning of terms they used by rephrasing what they had said or asking for further definition. This ensured that I had not misinterpreted their comments. During the final interview, I orally presented my interpretations of changes or stability in their thinking and instruction and asked them to comment. Both teachers concurred with my interpretations of their beliefs about the cur-

riculum materials, mathematics, and pedagogy.

**Segment analysis.** The segment analysis used all observed lessons to track the format and focus of each teacher's instructional practice across the school year. Segments are bounded by shifts in the structure or focus of activities within a lesson. After I divided each lesson into segments, I coded each segment for length in minutes, instructional format, the teacher's role, the teacher's focus, student behavior, and expectations for student cognition.

A second researcher also segmented and coded several days of field notes from observations of each teacher to check the reliability of my coding. All discrepancies between our coding were resolved by revising and thereby clarifying the definitions of segment codes to make them more precise. The same researcher also checked my coding of problematic or ambiguous segments. This rechecking and revising of codes resulted in 100% agreement on coding of segments.

Lesson segments were coded as "procedures" if the teacher's focus was on the presentation or execution of standard algorithms or the steps to complete an instructional activity. Segments were coded as "correctness" when the teacher was primarily concerned with the correctness or accuracy of students' answers. Segments in which the teacher focused on the mathematical meaning of problem-solving strategies, algorithms, operations, and problem situations and the relations between quantities were coded as "conceptual understanding." Segments were coded as "mathematical processes" if the teacher modeled or elicited from students reasoning about mathematical ideas, justifying solutions, identifying patterns, and making and testing conjectures. When a teacher's primary focus was on organizational and management issues (e.g., passing out materials, changing seat assignments, collecting permission slips), transitions at the beginning and end of mathematics instruction or be-

tween activities, or on an event outside the classroom while the students completed seat work or took a test, the code "organization or management" was used.

## Findings

The analyses showed a striking contrast. These two teachers differed in what they learned from the materials and in how they engaged the materials as a support for their learning. In this section I articulate these differences.

There were many similarities between the teachers and the contexts in which they worked. Both taught in schools with large populations of at-risk students and described the students in their classes as generally below average in mathematics. Though Ms. Clark and Ms. Ross sat on the district mathematics committee, neither had attended other staff development programs focused on mathematics or mathematics instruction for at least 5 years. For several years both had used a traditional Addison-Wesley mathematics textbook that was mandated by the district. Both had volunteered to pilot test the *Investigations* curriculum.

The teachers attended the same 2-day workshop on the *Investigations* materials in August with six teachers from other elementary schools in the district. At the workshop, teachers were encouraged to follow the materials closely and given an overview of the materials' organization and the topics at each grade level. The facilitator demonstrated instructional activities, with teachers taking the role of students who were developing and discussing problem-solving strategies. After the workshop the district mathematics coordinator gave each teacher a sequence of *Investigations* units matched to the district mathematics guidelines for grade-level topic coverage. During the school year, the curriculum materials served as the teachers' only source of professional development in mathematics and mathematical pedagogy. Neither collaborated with other teachers, and no adminis-



trator observed or critiqued their mathematics instruction or use of the curriculum materials.

Both teachers reported that they did not feel pressure from parents to use a particular approach to teaching mathematics. However, they were concerned that their students would be expected to know certain information (e.g., standard multiplication algorithms, multiplication facts) at the next grade level and on the state-mandated standardized tests. Both cited these expectations for content coverage when explaining their decisions to teach mathematical content not included in the *Investigations* curriculum.

Both teachers said that during October and November they read the *Investigations* materials page by page, including all the sections with content for teachers. Ms. Ross characterized her reading as "dutiful" (interview, 5/97). She made margin notes about the steps of instructional activities, highlighted points to clarify for students, and starred examples to use. Similarly, when she used *Investigations*, Ms. Clark highlighted important content to cover and made notes in the margins about the steps of instructional activities. After teaching lessons, she looked back at her highlighting to make sure she had covered the required content in preparation for the next lesson.

#### Ms. Clark: A Story of Stability

Ms. Clark held a tightly integrated set of beliefs about her own mathematical efficacy, mathematics, the purposes of mathematics instruction, student learning, and the teacher's role in instruction. Her instructional practice was consistent with her beliefs. During the school year, her beliefs did not fluctuate, and her practice changed only superficially and briefly while she used *Investigations*.

**Self-efficacy and beliefs about curriculum materials.** Ms. Clark was confident of her mathematics knowledge and her ability to teach mathematics. When asked to characterize her own abilities in mathematics, she replied with a laugh, "I can balance my

checkbook! I consider myself good as far as my studies, yes. I always was in school. If I didn't feel I was capable of doing the job, I wouldn't be doing this. Oh yes, I feel very comfortable and good about what I do" (interview, 10/96).

Regardless of the curriculum materials she used, Ms. Clark believed the essentials of fifth-grade mathematics remained the same. Because she was confident in her knowledge of what needed to be taught, she selectively used topics and activities offered by the materials.

When I started teaching, I just went by the curriculum. You know, whatever they said needed to be taught. But, as of now, in the last 15 years or so, I feel comfortable enough to where I can go through the curriculum and I can know the main things that they're going to need to know to go on to middle school. And I know the essential parts that need to be taught, the frills that could be cut out or will be picked up the next year or the next couple of years. Or, if possible, we get through all the essentials and then we can pick [the extra topics] up in the classroom. So I feel very comfortable in making those choices because I've been around long enough to know what needs to be covered, what needs to be taught in order for them to be able to succeed and go on to sixth grade. (Interview, 5/97)

In the past she had learned new ways of presenting information to students from mathematics curriculum materials. She explained, "You do things in a variety of ways, because, you know, everybody's constantly improving and you can't be rigid. You have to be flexible and look at all possibilities. Some may work with some kids. Some may work better [with other students] . . . I just never say, 'I know it all!' I mean there's no way you can do that" (interview, 5/97). Because she already had a repertoire of instructional strategies, she was not sure whether *Investigations's* extensive use of manipulatives would boost her students' standardized test scores as the district mathematics coordinator anticipated. "I'm anxious

to see—will it make a difference [to students' test scores]. Because I do a lot of hands on, visual things when I teach math, when I teach all subjects. [I'm wondering if] doing these additional things, will it help?" (interview, 10/96).

Opportunities to develop her new understandings of mathematics and pedagogy were not important in Ms. Clark's decision to pilot test materials. Her primary reason for volunteering to pilot test the *Investigations* curriculum was to have a chance to use the materials for a year before they were mandated by the district. She explained,

The first time I heard about [*Investigations*] was at the math meeting and, of course, they always extend to the math committee members the chance to be the pilot first . . . and you pilot because basically you get the materials, you get to know what the program is like before it starts. And you're able to work it through, explore the pros and cons to it, and by the time it's adopted you feel comfortable with it. I've always done pilots, so it doesn't bother me. It doesn't seem intimidating or time consuming, which it is. But if you do pilots enough you don't think anything about it. And if it's going to be the in thing, I might as well be involved in it. The first year through is easier than starting when it's adopted and then you're supposed to be a little more polished with it. (Interview, 10/96)

**Beliefs about mathematics and the aims of instruction.** In Ms. Clark's eyes, computational speed and accuracy distinguished successful from unsuccessful students. Throughout the year she encouraged her students by telling them she was teaching them the quickest and fastest way to get to the answer. She thought it was important to communicate that "math is like a game. If you listen carefully, listen to the instructions, you'll learn how to play the game, and it is a game. It's learning the patterns to it. There are certain methods, techniques. Once you learn those, you know how to do it" (interview, 5/97). Ms. Clark had suc-

cessfully learned the "rules" of mathematics and wanted to help her students become successful, too. These rules were the hierarchical canon of problem types, facts, and standard algorithms that, to her, constituted mathematics.

To facilitate students' learning, Ms. Clark believed math topics should be presented systematically from easier to more difficult. Each topic and its accompanying facts and algorithms should be mastered and then built on in successive lessons. Her description of how she taught multiplication the previous year illustrates her approach. "We started out with . . . a step-by-step introduction to multiplication. Doing simple multiplication. You know, 1 times 5 and you show the regrouping; this is a group of fives. It's like a progression. You start out easy and, step by step, showing the concept of how you regroup until they get to the larger numbers" (interview, 10/96). She believed that all students needed a firm foundation of prior knowledge before they moved to more difficult topics.

The instructional approach embodied in *Investigations* stood in sharp contrast to Ms. Clark's approach in many respects. *Investigations* describes learning as a long, slow process of developing increasing depth of understanding through repeated experiences with mathematical ideas. The materials assert that differences in students' understanding are not a cause for concern but a given in every classroom. Furthermore, the curriculum materials reject an emphasis on speed and rote memorization, portraying these as creating barriers to success in mathematics for some students. The materials encourage teachers to have students invent problem-solving strategies instead of memorizing standard algorithms.

In December I noted to Ms. Clark that, whereas the curriculum materials de-emphasized speed in computation, speed seemed important to her. She replied that students "have to have the basics" (interview, 12/96), noting that students need to be able to do calculations when they go to

the store or balance their checkbook because they would not be able to carry a calculator around everywhere. Throughout the year, she reminded students that problem-solving algorithms she was teaching them provided the swiftest way to solve math problems. "I told you in the beginning that [the purpose of] math [class] is to show you the quickest and fastest way to do math" (observation, 11/96). "We are still doing the short method of multiplying with zeros. . . . Like I've always said, [math] is the shortest, the quickest, and fastest way" (observation, 5/97). For Ms. Clark, fluency with standard algorithms was not a barrier to instruction but an indication of success.

Both Ms. Clark and *Investigations* emphasized that students needed to understand mathematical concepts; however, they differed in their definition of mathematical concepts. By understanding mathematical concepts, Ms. Clark meant the memorization and correct execution of standard algorithms. As she told her students, "We were teaching you to understand it, showing you the rules and how to apply them. It was just a matter of you applying the rules" (observation, 5/97). *Investigations* gives a very different meaning to understanding concepts. In *Investigations*, understanding refers to familiarity with the magnitude of numbers, mathematical relations, and the meaning of mathematical operations and situations.

As the following analysis shows, these differences in philosophy and practice played an important role in what and how Ms. Clark learned from the curriculum materials and how the materials informed her instruction.

**Mathematics instruction.** To observe Ms. Clark teach mathematics was to see the prototypical traditional mathematics instruction (Good, Grouws, & Ebmeier, 1983; Smith, 1996; Stodolsky, 1988). She frequently described her style of teaching as "walking the students through." She relied heavily on demonstrating algorithms on the chalkboard. However, recognizing that the

same presentation may not work for all students, at times she also drew pictures, demonstrated with manipulatives, and asked students to explain the steps of algorithms to one another. Fast-paced descriptions accompanied her demonstrations. Often she asked whether students understood. When a student asked a question, the teacher repeated the steps to the algorithm until the student recognized which step he or she had missed. Ms. Clark's lessons concluded with students completing assigned problems individually at their desks. Students took unfinished work home. The next day typically began with correction of the previous night's homework and the demonstration of another algorithm.

**Adapting lessons:** Given her view of mathematics and learning, Ms. Clark found it necessary to adapt *Investigations* lessons to compensate for her low-achieving students' lack of prior knowledge. She explained that "higher-level kids would probably already have achieved the concept. Or, well, let's not say 'achieved.' They would have already been introduced to it. Not mastered it, but already introduced to it. . . . The concepts would already be basically sort of formed and they would be able to just pick up on those real easy" (interview, 5/97). For example, in October she spent 2 hours on one of *Investigations*'s "Ten-Minute Math" activities. According to the curriculum materials, these activities were meant to be done in a spare 10 minutes outside of math time as "practice in key concepts, but not always those being covered in the unit." The teacher, however, assumed that activities in the curriculum built on each other and that each concept should be taught to mastery. She explained, "We basically spent two classes on a 10-minute activity of exploring data, of recording it, how are we going to chart it, how are we going to put it down. Then, of course, I did expand on when we do graphs [and] what are the parts of the graph. The title, have to label it, two labels. I may have stretched it out a little more because I felt it was important

so that they would understand more clearly. When you have those bewildered faces and they're sitting there looking up at you, you pick up on that real quick. You could just read from the book and not look up, but when you're explaining things and you see the bewildered look, you have to expand on it to make sure they do get that. . . . When you're doing new programs, you have to be able to sense the need of when to go on, to make sure that it is understood; otherwise you're going to have to go back and reteach it all again" (interview, 10/96).

*Reinterpreting lessons:* Not only did Ms. Clark change the length of lessons, but she also changed their essence. She saw the teacher's role as transmitting mathematical knowledge to students. To her, finding alternative problem-solving strategies and discussing mathematical ideas were unnecessary distractions from the aims of instruction. To *Investigations*, they were essential to understanding mathematics. The following example from the first week in December is typical of Ms. Clark's instructional practice using *Investigations*.

The *Investigations* materials describe this activity as follows:

In small groups students solve number puzzles by sharing all four clues and working together to find one or more numbers that fit all the clues. Students also write sets of clues to make their own puzzles. Their work focuses on

- reasoning about number characteristics such as multiple, factor, even, odd, prime, and square
- developing, discussing, and comparing strategies for solving problems
- understanding that problems may have one, many, or no solutions
- writing about mathematical reasoning. (Kliman, Tierney, Russell, Murray, & Akers, 1996, p. 40)

Below is an excerpt from my field notes from the lesson Ms. Clark taught. At this point, she had seated students in groups of four and given each group an envelope with four puzzle clues. After writing the

puzzle clues on the chalkboard, she proceeded with the activity.

On chalkboard:

- 1) My number is a factor of 60.
- 2) The sum of the digits in my number is 3.
- 3) My number has 2 digits.
- 4) One factor of my number is 4.

Ms. Clark calls on students to read the clues out loud. She then asks rhetorically, "Which of these clues is going to help us narrow it down?" She chooses clue number 1. Ms. Clark calls on students to list factors of 60, which she writes on the board:

1, 2, 3, 4, 6, ——— 10, 12, 15, 20, 30, 60

Ms. Clark then says, "We have explored all the possible ways we can get to 60."

She says, "Let's look at clue number 3." She crosses out all the one-digit numbers, because the number has to have two digits. Ms. Clark says clue number 2 says that the sum of the digits must equal 3. She says that 1 plus 0 does not equal 3 and crosses off 10. One plus 5 does not equal 3, so she crosses off 15. She continues crossing off 20 and 60.

On chalkboard:

1, 2, 3, 4, 6, ——— 10, 12, 15, 20, 30, 60

Ms. Clark demonstrates double checking that 12 and 30 fit first three clues. . . . She writes the factors of each two-digit number under the number on board. She asks the class which has a factor of 4.

Students say 12. (Observation, 12/96)

As this excerpt shows, the teacher's enactment of this activity reinvented the aims of the lesson and the role of the students in mathematics learning. She converted what was meant to be a small-group activity into whole-class recitation. She did the reasoning for students, deciding which strategy to use and pondering aloud whether the answers were correct. The students' role was limited to listening to the teacher, supplying mathematical facts, and reading what was written on the chalkboard. They did not reason about number characteristics or develop, discuss, or compare problem-solving strategies. Nor did students write or

otherwise communicate about mathematical reasoning.

**Focus.** In the number puzzle lesson discussed previously, Ms. Clark focused on procedures and correct answers. This focus dominated her mathematics instruction across the school year. During the 869 minutes I observed her teaching, she emphasized procedures and correctness in lesson segments totaling 537 minutes or 61.8% of the observational time (see Fig. 1). She emphasized conceptual understanding or mathematical processes during only 24 minutes of a single lesson (2.76% of all observations). During this lesson the teacher had students count by multiples of 25, 50, and 100; discuss the relation between 25 and

100; make conjectures about multiples; and explain their problem-solving strategies. During the remaining 308 minutes of scheduled mathematics instruction (35.44%), Ms. Clark was concerned with organizational and management issues.

*Reinterpreting the content for teachers:* She interpreted what the new curriculum materials offered in light of her beliefs about mathematics and pedagogy and her previous experience with curriculum materials. She expected the materials, like others she had used over the past 2 decades, to provide a sequence of lessons and accompanying instructional materials. Dialogue boxes, for example, presented sample dialogues to help teachers prepare for class-

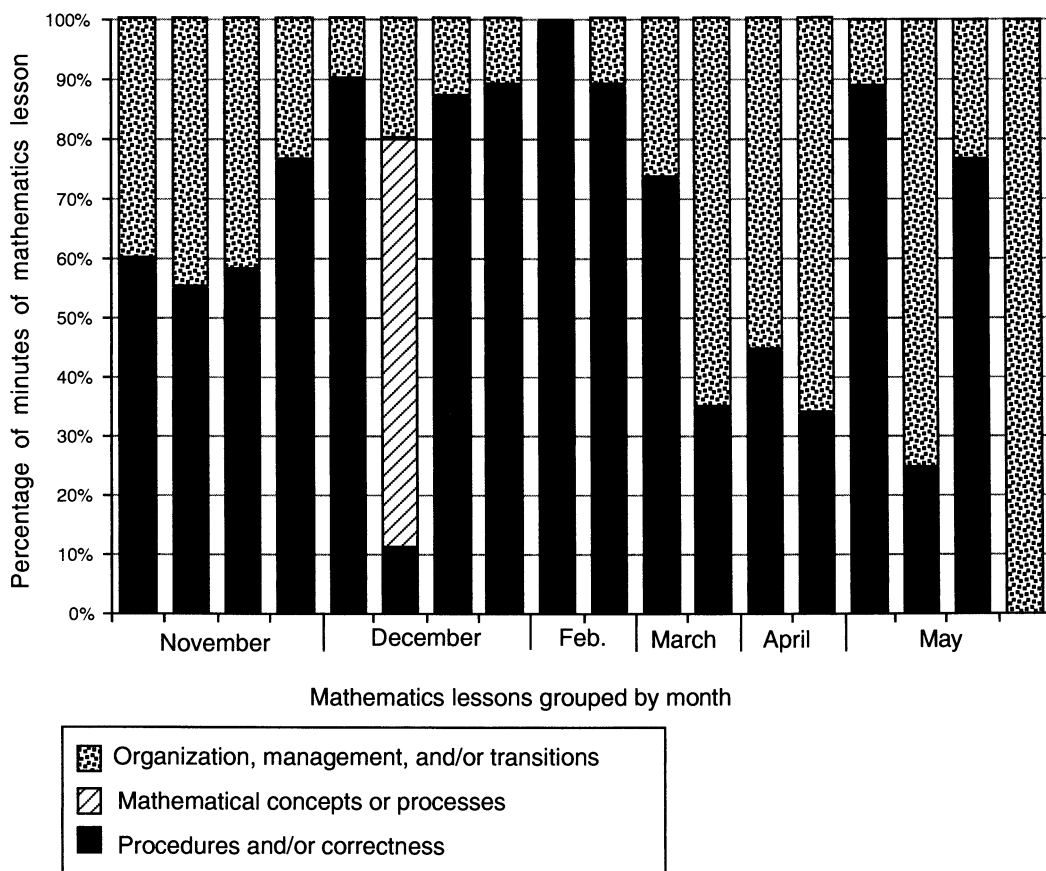


FIG. 1.—Ms. Clark's focus during mathematics instruction

room discussions. The dialogues were written in a scriptlike format, and Ms. Clark assumed they were to be read aloud as a role-play by the class. Most of the time she skipped this “activity” and explained that “we were supposed to go through and do this dialogue with the kids. I found by the time we got to this, we had already done this dialogue. It wasn’t verbatim, but we had basically gone back and forth and done this at the chalkboard. So, I found in those cases I wasn’t repetitious. I mean, we’ve been repetitious enough. Some of those I did not do because we had already [done them] at the board. We wound up explaining, showing, saying the same thing” (interview, 5/97). The instructions given for the dialogue boxes stated that they were intended as an exercise for teachers to prepare for instruction. Nowhere did the curriculum materials suggest that the dialogue boxes were to be used with students.

*Growing frustration:* As she continued to work with the curriculum materials, Ms. Clark discovered that they did not provide students with standard problem-solving algorithms in lessons on multiplication, division, decimals, and fractions. She wondered how the curriculum developers could expect students to solve “abstract” and “hands-on” problems without these basic tools. The teacher concluded that her students lacked the prior knowledge they needed to be successful with *Investigations* instructional activities. She articulated her dilemma concisely: “Do you zip right through or spend the time so kids can get the depth and grasp the material?” (interview, 12/96).

In addition, she found the materials to be cumbersome and overly time consuming. In the fall she was aware that the curriculum materials would take more preparation time. “It’s not one you can pick up the book and just walk in and say, ‘Let’s turn to page 2 and let’s do this.’ I’ve got to be prepared. And the materials, most of them are hands-on, exploratory. I have to have the materials and everything ready.

Otherwise I waste a lot of time” (interview, 10/96). After one lesson she remarked that it had taken her an hour to read all the related text including lesson overviews, teacher notes, and the “about the mathematics in this unit” section. She noted having to read 11 pages to prepare for another lesson. “It skirts all the way around the point and comes in through the back door,” she explained (interview, 12/96). She suggested that the curriculum developers had to write curriculum with all teachers in mind and that what she saw as excessive wordiness may be helpful to new teachers for whom mathematics “was not a strong point” (interview, 12/96): “If you were a new teacher it would be very helpful, because it’s sort of reinforcing how you talk to the kids, how you’d walk them through. After you’ve taught a few years—I’m not saying it to be conceited or whatever you want to call it—but after you’ve taught a few years most of these things you guess” (interview, 5/97).

Based on her growing frustration, Ms. Clark put *Investigations* back on the shelf and returned to her more traditional Addison-Wesley mathematics textbook in January. In an interview in early February, she explained her decision in terms of student learning. The traditional textbook would help her “fill the holes from *Investigations*” by doing more of the “drill and skill” (interview, 2/97) that her low-achieving students needed.

Ms. Ross: Teacher Learning and Instructional Change

Ms. Ross hoped that the new curriculum would bolster students’ confidence and prior knowledge. As she used the *Investigations* materials, she made dramatic changes in her approach to instruction: her focus shifted from procedures and correctness to conceptual understanding and mathematical reasoning. Moreover, justifications she gave for her practices became aligned with *Investigations* justifications. What did not change was her conviction

that confidence and prior knowledge were the keys to success in mathematics.

**Self-efficacy.** When asked to name someone who was not good at mathematics, Ms. Ross nominated herself. She recalled struggling with mathematics in grade school and steered clear of college majors that required too many math courses. "I felt like I was floating out there in space somewhere," she said, referring to a college statistics course. "I had no foundation, and I learned right then how important it is to make sure kids have prior knowledge. Before you go on to teach them anything, they have to have something to hold onto. And I didn't, and I didn't like it" (interview, 10/96).

Echoes of Ms. Ross's own experiences surfaced in her explanations of the essential ingredients for students' success in mathematics. "I think if we can help kids to enjoy mathematics, if they enjoy it, they are going to—how could you not feel confident about something you enjoy doing? And I think therein lies the key. The key to success is feeling that you can do it" (interview, 10/96). She reasoned that if students enjoyed mathematics, they would try harder and learn more as a result. As they gained a base of mathematical knowledge, they also would gain confidence in their mathematical abilities and be willing to try even more challenging work.

**Beliefs about mathematics and curriculum materials.** Unlike Ms. Clark, Ms. Ross did not see a clear structure to mathematics. During her years as a teacher, she had relied on her curriculum materials and the objectives for the state's standardized tests to direct the content of and emphasis in her instruction. She used "the curriculum pretty heavily and teacher resource materials to clue me in as to what it is that I'm supposed to convey to the children, and I rely on that so much because I've never thought of myself as a mathematician. So I don't have—I guess I don't have a real broad philosophy of teaching math. I just look at the curricu-

lum and start plugging away" (interview, 5/97).

When Ms. Ross agreed to pilot test *Investigations*, she hoped it would provide a coherent set of hands-on activities that supported her quest to make mathematics instruction enjoyable and less stressful for students with low reading skills. She explained, "That's what interested me about this math program, because there is no text, and there was a lot of hands-on and a lot of activities" (interview, 10/96). In previous years, Ms. Ross had students use mathematics manipulatives only sporadically and mainly to demonstrate mathematical operations and to help figure out the answers to problems. Because she assumed that *Investigations* would support her goals of using more manipulatives and building students' prior knowledge and confidence, closely following *Investigations's* lesson plans seemed a sensible way to proceed. She explained, "I think with this series there is no way you can miss because everything is so clearly spelled out. So far it's been, the teaching of it has been a lot of fun and I feel like it is something I can do. I don't feel threatened about piloting this new program. It all makes a lot of sense to me so I'm hoping it will make sense to the children as well" (interview, 10/96).

**Mathematics instruction.** Ms. Ross followed the structure of the lesson plans as detailed by the curriculum materials and used the problems and activities suggested in the materials. As directed by the materials, she asked students to collaborate, diagram, write, and discuss problem-solving strategies, observations, and solutions. She frequently kept the curriculum with her and often used its suggested wording for introducing problems, giving explanations, and asking questions verbatim. Across the school year I observed 1,139 minutes of Ms. Ross's mathematics instruction. She emphasized procedures and correctness in lesson segments totaling 233 minutes or 20.5% of the observational time, conceptual understanding or mathematical processes during

747 minutes or 65.6% of observational time, and organizational or management issues during 159 minutes or 14% of observational time.

Observations of Ms. Ross's teaching revealed profound changes in her focus during mathematics instruction, which shifted from correct answers and the steps students needed to follow to complete an activity to conceptual understanding and mathematical reasoning. This change occurred by the first week in November and was sustained throughout the remainder of the school year. During October, Ms. Ross focused on procedures and correctness in lesson segments totaling 93.8% of observational time as compared to 9.6% from November to May. She did not emphasize conceptual understanding or mathematical processes during any segments of her October mathematics lessons. In contrast, Ms. Ross focused on conceptual understanding or mathematical processes in segments totaling 75.3% of observational time from November through May. These changes are depicted in Figure 2. Analysis of lesson segments also revealed that, by January, Ms. Ross shifted from accepting simple reports and descriptions of strategies, observations, and solutions to expecting more complex mathematical reasoning and explanations from her students.

The following two examples from the field notes illustrate these changes in instruction. The first is from a lesson taught at the end of October. In this activity students circled multiples of two on a hundreds chart and then wrote about patterns they observed. In the last segment of this lesson several students described their observations to the class. (Names are pseudonyms.)

Ms. Ross says she hopes that all students have an observation.

"Who would like to share a pattern that they saw? David, I would like you to go first because I love what you wrote on your paper." She asks David to come

up front and to read his observation when all the students are quiet.

David reads, and Ms. Ross repeats that all of the yellow numbers are even and all of the white numbers are odd.

Next student reads, "The yellow are even. They are going by twos. The ones that are white are odd. They are going by every other number. There are five yellows, and there are five whites."

Jacob reports that he noticed that all the numbers that end with 2, 4, 6, 8, and 0 are colored.

Luther says, "50 are white and 50 are yellow."

Ms. Ross responds "very good" to each student. (Observation, 10/96)

In this example, the teacher encouraged student participation; however, she did not push students for more mathematical thinking. She did not ask them, for example, about the relations between even numbers and multiples of 2 or why there are 50 multiples of 2 between 1 and 100. She accepted students' answers without distinguishing which were and were not mathematically relevant.

As the year progressed, the teacher's acceptance of simple reports and descriptions of observations and solutions was displaced by an expectation of more complex mathematical reasoning and explanations from students. This is illustrated by an excerpt from a lesson taught in April in which students developed several solutions for dividing a square into fourths. Students used a geoboard to explore possible designs and then recorded their solutions on a worksheet of squares. As the students worked, they often noticed and copied one another's designs. Audralyn's design was particularly popular (see Fig. 3). Toward the end of the lesson, Ms. Ross asked Alita to come to the overhead projector and demonstrate that Audralyn had divided the rectangle that made up half of the square equally into fourths. In contrast to the lessons taught in the fall, in this lesson Ms. Ross did not stop when a student gave a correct answer. Instead, she treated Alita's answer as a conjecture and asked Alita to demonstrate her



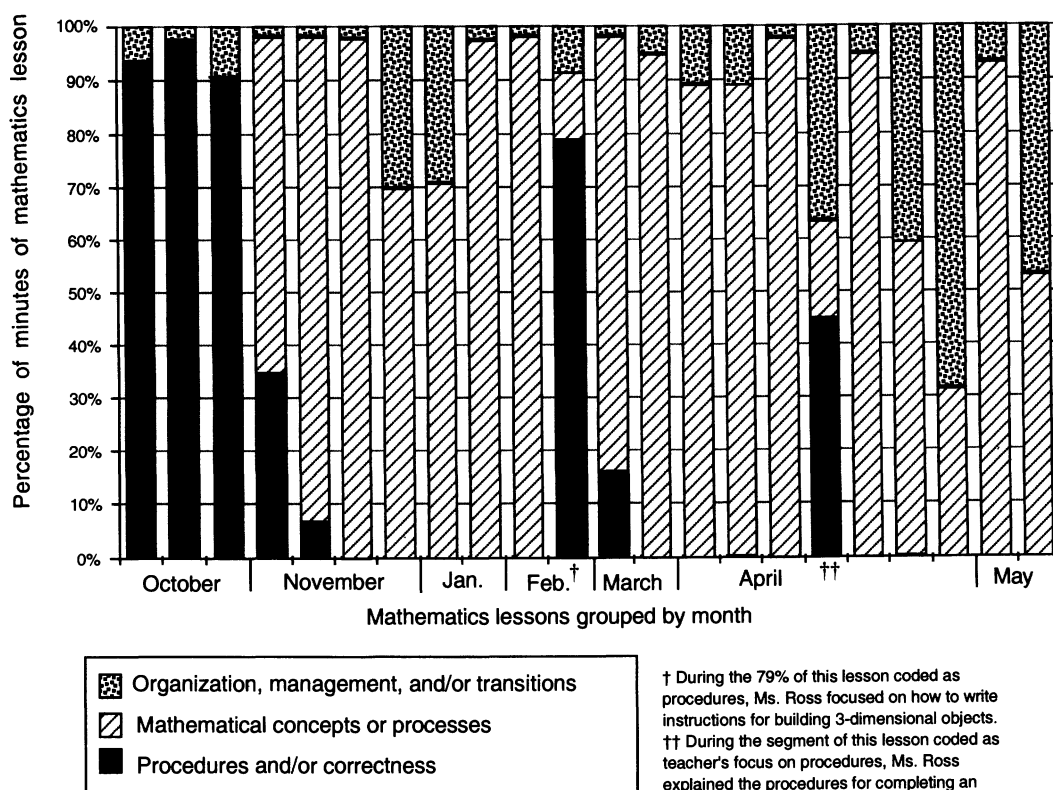


FIG. 2.—Ms. Ross's focus during mathematics instruction

reasoning and provide evidence to support her conjecture. The following is from my field notes.

Alita explains, "These two triangles put together is a rectangle."

Ms. Ross asks what else she can tell her about the two triangles, the two shapes.

Alita says, "They're equal."

Ms. Ross repeats, "They're equal. How can you prove that they're equal?"

Alita replies, "Because when you put that line in the middle they look the same."

Ms. Ross repeats, "When you put the diagonal line, they look just the same. She's going to do something." Ms. Ross puts cutouts of the two triangles on the overhead. She says, "These are the two triangles, and when we put them together we get—a rectangle." Alita said she believes those triangles are exactly the same. The teacher says, "Alita, using

those cutout pieces of paper, prove to the class that they are exactly the same. Use the two triangles on the overhead. How can you prove that they are the same?"

Alita turns one triangle and puts it on top of the other.

Ms. Ross says, "Yes, madam, when she stacks them up, they are one right on top of the other—exactly the same. Okay. Thanks, Alita."

The class applauds. (Observation, 4/97)

### *The aims of mathematics instruction.*

Ms. Ross reported that when she taught multiplication the previous year, she wanted students to "master facts and know the circumstances under which multiplication was the appropriate strategy" (interview, 10/96). She also wanted students to develop confidence and not be hindered by a lack of prior knowledge. As she expected, the materials offered a plethora of hands-on

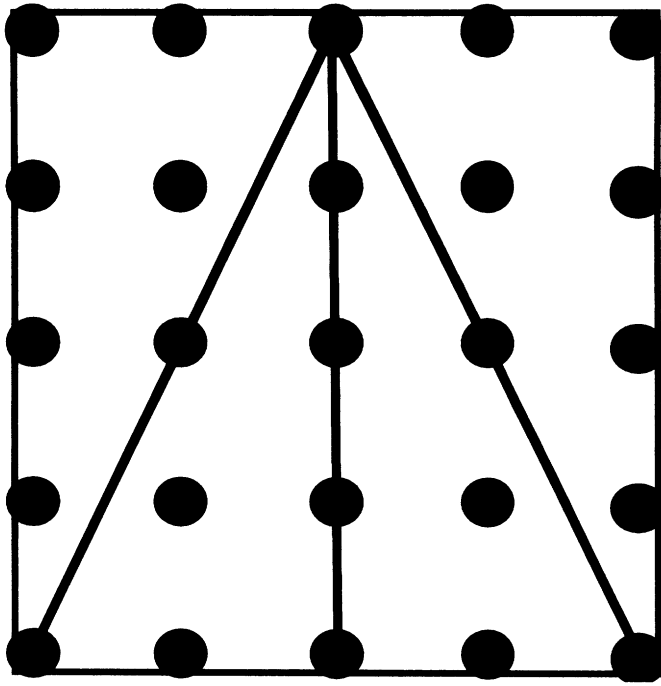


FIG. 3.—Audralyn's design for dividing a square into fourths

activities that reduced the reading demands on her "reluctant readers." By late October Ms. Ross also had evidence that the materials, though challenging, supported her aim of building students' confidence in mathematics. "Every child in this room, I think, feels that they can do what they have been asked to do so far. Now the writing, explaining when they were doing the cluster problems, looking for patterns—that was challenging. And most of them were able to figure the problems out in their heads, and seeing the pattern and being able to predict helped them with that" (interview, 10/96).

Toward the end of the year, Ms. Ross still highlighted developing students' confidence as the primary aim of mathematics instruction and lauded the support the materials gave her. For example, when asked to complete the sentence, "Math is——," she replied,

I think this is silly, but I want them [the students] to say math is fun. Because if I

have a philosophy at all it's to help them relax with math because I think when any of us, adults or children, are uptight about a subject it's very hard to penetrate and understand. But, if you are relaxed, then you're more open to learning. So I would like them to be relaxed and have fun with it. . . . So that's one of the strengths of this program. The kids have very much enjoyed it, and I think they have relaxed with it. And we spend a great deal of time on math. More instructional time this year than I've EVER spent on math before, and the children are always amazed when it's time to go to lunch. (Interview, 5/97)

By following the directions for instructional activities closely, Ms. Ross made other discoveries that she had not anticipated and articulated new justification for pedagogical decisions and additional goals for mathematics instruction. As the materials directed, Ms. Ross asked students to demonstrate, write, and discuss their mathematical ideas. Her students, for example, used 100 charts to explore patterns in mul-

titles, interlocking cubes to investigate three-dimensional objects, and geoboards to develop divergent solutions for dividing a square into fractional parts. Enacting these lessons and observing students' responses gave the teacher a window on how manipulatives could be used as tools for developing problem-solving strategies, communicating about mathematics, and exploring mathematical relations. In October, she explained, "You know, we were always taught there was only one way to solve an addition problem, and now we are teaching kids to look for different ways, that there are many ways to come to the same conclusion. So that's another big shift for me and something that is exciting for me to discover. And I really hadn't thought about it at the time I started working with this program" (interview, 10/96).

In May, I asked if her goals for mathematics instruction had changed during the school year. She talked about developing divergent problem-solving strategies as a goal of mathematics instruction. "I think that what we were really focused on this year was helping them understand that there are many different ways to solve a problem. . . . I mean there were strategies for problem solving that we taught in the other math curriculum, but I don't think we were open to having them explore and come up with different ways of solving problems" (interview, 5/97).

Having students demonstrate, write, and speak about their mathematical ideas not only demonstrated to Ms. Ross that students could develop alternative problem-solving strategies but also that communicating itself was an important part of the process of learning to reason mathematically. She explained that "asking the children for explanations of their thought processes is something that I've never done before. . . . I always knew that writing was important in math, but it was always hard to get the writing part, and that's built into this program. And writing it down helps kids to really think it through" (interview,

10/96). Similarly, she found that having students discuss ideas with a partner helped them deepen their understanding of mathematical ideas. In previous years, she had students work alone because she believed that the at-risk students she taught would be distracted and not attend to their mathematics work if they had a partner. The *Investigations* materials suggest that communicating about mathematical ideas and situations helps students clarify their thinking as well as become better at communicating. Thus, the justifications Ms. Ross articulated were in concert with those advocated by the materials.

Ms. Ross adopted *Investigations's* goal of developing students' understanding of the relations between numbers. By February, for example, she excitedly told me about the creative ways that students solved 28 times 4. One student multiplied 20 times 4, then added 9 times 4 and subtracted 4. She said that these students might still get a "wacko answer" (interview, 2/97) when they solved a multiplication problem, but, in contrast to children who were only taught the standard algorithm, they would know when they got such unrealistic answers because they had developed number sense. In addition, Ms. Ross de-emphasized memorization of facts and speed in computation during mathematics lessons. She explained, for example, that she stopped using timed tests to evaluate students' mathematical knowledge as she came to believe that students' understanding was more important than how quickly they could recall facts. At the end of the year she reported,

One thing that I think is different is that they have a better sense of numbers, of how numbers build. They see the patterns in number, I think. . . . They just have a better basic understanding of what it's all about rather than just memorizing steps and solving a problem. . . . They have a deeper understanding. I think computation has suffered in the process, and I hope that as they go along they're going to make that up because we didn't do a lot in terms of computation.

And I think if they have the basic understanding, it's going to help them master the computation when they come across it and when they're introduced to it. (Interview, 5/97)

As her students explored mathematical relations, Ms. Ross noted changes in her own knowledge of mathematics. For example, in November, she noticed the relation between multiples of 3 and 6 for the first time. That is, a multiple of 6 is always double the multiple of 3. As she pointed to a 100 chart to explain the relation to me, she realized the same pattern was true for multiples of 2 and 4. However, her own limited understanding of mathematical relations at times hindered her ability to guide students. Ms. Ross did not always distinguish between mathematically relevant and irrelevant connections students made to their prior mathematical knowledge. For example, during one lesson students circled multiples of 6 on a hundreds chart and wrote about the patterns they noticed. Erica reported that the circled numbers could be connected to make two symmetrical trapezoids (see Fig. 4). Ms. Ross told me she was excited that this student had drawn on her prior knowledge of shapes and symmetry. She did not seem to notice that the observation did not contribute to the student's understanding of multiples.

Although she had students explore ideas with manipulatives, invent their own problem-solving strategies, communicate their mathematical ideas, and search for patterns, Ms. Ross did not abandon teaching standard algorithms altogether. She was concerned that her students would be expected to know the standard algorithms in the next grade and on the state's standardized tests. In January, after finishing *Investigations's* multiplication and division unit, she taught the standard multiplication algorithm. Later in the year, she drilled students on standard addition and subtraction algorithms, place-value identification, and reducing fractions during daily morning

seatwork. In the spring, she also modified or skipped lesson activities based on her assessment of students' understanding, her knowledge of math, coverage issues, and consideration of organization of materials and her growing understanding of the aims of *Investigations's* approach to mathematics instruction.

**Use of content for teachers.** Ms. Ross reported that the teacher note and dialogue boxes helped her learn about teaching mathematics. She explained that the teacher notes "would just help my basic understanding of what it is that I was, you know, trying to get across to these kids" (interview, 5/97). For instance, before one lesson, Ms. Ross read a teacher note about common errors students make. During the lesson she observed several students making similar errors as they circled multiples on a 100 chart. After the lesson she reread a teacher note that explained typical student errors and then used this information to consider how she might guide students as they continued the activity the following day. She began the next lesson by calling students' attention to common errors and asking them how the errors might be avoided.

In contrast to Ms. Clark, Ms. Ross used the sample dialogues, as intended, to help her prepare for lessons and anticipate how her students might talk and think about mathematical ideas. At the end of the school year she exclaimed, "I loved the dialogue boxes where they gave examples of children's conversations trying to work through things, because it helped me anticipate how my kids would be thinking" (interview, 5/97). She explained that she "always read the dialogue box. . . . Some of it was a little too sophisticated. But a lot of it was right on." In April, for example, she taught a fractions lesson in which students had to find ways to divide irregular shapes, "crazy cakes," into equal pieces. Before the lesson, she read the dialogue box and learned that sometimes students use symmetry to find ways to cut crazy cakes in half. This helped her anticipate problem-

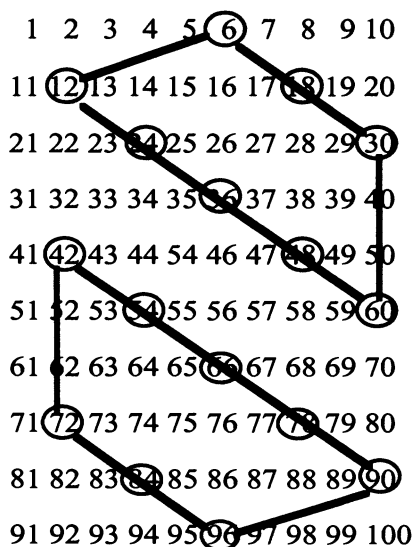


FIG. 4.—Erica's trapezoids on the 100 chart

solving strategies her students might develop.

## Discussion

It is commonly thought that in order for the current wave of instructional reforms to be successful, teachers will need extensive new knowledge about pedagogy and subject matter. Curriculum materials could be an attractive option for supporting teacher learning on a wide scale because they might offer ongoing support that is intimately connected with practice. This study provides some support for the conjecture that curriculum materials designed to convey subject matter and pedagogical content knowledge to teachers may facilitate teacher learning. Ms. Ross adopted a new approach to teaching mathematics, with curriculum materials as the primary source for her professional development. Her instructional practices and, more importantly, her focus during mathematics instruction and her rationales for practices changed in the direction the curriculum materials advocated. The instruction students experienced and her thinking about mathematics teaching and learning were different at the beginning and at the end of the school year.

The changes did not occur all at once. Instead, this case supports others' findings that teacher learning develops over an extended period (e.g. Blumenfeld et al., 1994; Richardson, 1996).

My findings also illustrate limitations of curriculum materials as a professional development tool. Put simply, curriculum materials do not always support teacher learning. That is, Ms. Clark's use of the *Investigations* curriculum did not result in change in her mathematics instruction or in related beliefs and practices, although she had similar support from the materials and the school district as did Ms. Ross. Throughout the school year, Ms. Clark continued to use her prior approach to teaching mathematics, emphasizing memorization and correct execution of standard problem algorithms. She did not ask students to write about and discuss mathematical ideas or develop nonstandard problem-solving strategies.

It would be unfair to conclude that Ms. Clark did not learn through her engagement with the *Investigations* materials. What she learned, however, was not what the curriculum developers intended to convey to teachers. She discovered that the materials

did not support her teaching of standard algorithms and computational speed, required prior knowledge that her low-achieving students did not have, presented mathematical topics in a seemingly unsystematic order, were time consuming to use, and, by allowing a range of alternative problem-solving strategies, conveyed to her students that mathematics was not an exact science.

### Opportunities to Learn

The findings from the cases presented here suggest that opportunities to learn may not be synonymous with the form or content of professional development. Rather, these opportunities can involve the dynamic experiences that make information about subject matter and pedagogy available to teachers. Learning from curriculum materials encompasses a broad range of interactive experiences including enacting instruction, reading the materials, and using the materials when collaborating with colleagues.

**Enacting instruction.** The contrast in the experiences of Ms. Clark and Ms. Ross shows how enacting instruction can create different opportunities to learn. Ms. Clark altered lessons to offer students the structure she felt they needed to complete activities correctly. Her enactment of *Investigations's* lessons curtailed invention and discussion of alternative problem-solving strategies. This, in turn, reduced the information available to the teacher about students' capabilities and thinking about mathematics and the usefulness of alternative strategies in mathematical problem solving.

Ms. Ross's enactment of the instructional activities provided greater opportunities for learning about students' abilities, the aims of mathematics instruction, and the approach to teaching mathematics. She found that her students were able to develop alternative problem-solving strategies, discover mathematical patterns, use manipulatives to explore and demonstrate their mathematical ideas, collaborate on

problems with peers, and communicate their mathematical thinking verbally and in writing.

**Reading curriculum materials.** Although their differing enactment of instructional activities provided divergent information to these two teachers, the curriculum materials presented similar information. Conceptualizing opportunities to learn as dynamic experiences illuminates why teachers may draw very different conclusions from similar professional development resources. Ms. Ross's and Ms. Clark's interpretations of the content for teachers illustrate this point. Both reported reading the materials thoroughly. However, Ms. Ross expected curriculum materials to support her own learning about what and how to teach. She reported that the guidance in the teachers' notes was particularly helpful. She also used the dialogue boxes to learn about how students might communicate their mathematical ideas.

Ms. Clark, in contrast, saw the teachers' notes and other content for teachers as not relevant for an experienced teacher who was comfortable with her knowledge of mathematics. This coincides with Smylie's (1995) conclusion that teachers may dismiss information they interpret as not relevant or useful, especially in relation to problems of practice that they find meaningful. In addition, she assumed that the dialogue boxes were role-play activities for students. Ms. Clark's interpretation of the content for teachers reflected her expectations of curriculum materials as providing instructional activities. She did not expect the materials to educate her about mathematics or mathematical pedagogy.

### Influences on the Construction of Opportunities to Learn

These cases corroborate the influence of students on instruction (e.g., Prawat & Jennings, 1997) and, additionally, on teachers' evaluation of curriculum materials and their construction of opportunities for their own learning. Both Ms. Ross and Ms. Clark,

for example, were willing to adapt suggested activities to accommodate the perceived needs and responses of their low-achieving students.

The cases also highlight the influence of teacher identity (e.g., Spillane, 2000), the constellation of a teacher's beliefs and knowledge about subject matter, learners, pedagogy, and self as a teacher and learner. Teachers' construction of opportunities to learn may be understood in terms of the convergence of several interrelated beliefs rather than a particular category of beliefs in isolation. For example, in Spillane's (2000) case of Ms. Adams, the convergence of her low mathematical self-efficacy with concerns about her students' moral development was pivotal to her minimal engagement with resources related to mathematics reform. In contrast, Ms. Ross's low mathematical self-efficacy converged with her concern for developing students' confidence and resulted in her embracing reform-oriented resources for learning about mathematics and mathematical pedagogy.

In addition to the combinations of beliefs they hold, teachers may differ in which beliefs are most integral to their identity (Pajares, 1992). Considering how beliefs converge and how integral they are to a teacher's identity may add to understanding of how beliefs may act as both influences on and targets of change. As a professional development tool, the *Investigations* materials were built on a particular view of the nature of mathematical knowledge and corresponding pedagogy. These targeted beliefs neither coincided nor conflicted with the beliefs most integral to Ms. Ross's identity as a teacher and learner. She did not have strong convictions about mathematics or mathematical pedagogy and relied on curriculum materials to guide her mathematics instruction. However, the beliefs most integral to her identity—the importance of developing students' confidence for learning mathematics and their prior knowledge—were compatible with what *Investigations* asked of her. The compatibility

between Ms. Ross's identity as a teacher and learner and the beliefs targeted by *Investigations* afforded an opportunity for her to learn about mathematics and pedagogy.

In contrast, the beliefs that were integral to Ms. Clark's identity as a teacher and learner of mathematics—her view of mathematics as a hierarchical cannon of rules, facts, and algorithms and her understanding of what it meant to learn and be competent in mathematics—were the same ones *Investigations* targeted for change. Far from being compatible, Ms. Clark's central beliefs conflicted with the stance the materials advocated. Her dismissal of the materials' value for teaching her students and supporting her learning can be understood in light of the conflict between her identity and the beliefs targeted for change.

In summary, this study began with the question of whether and what teachers might learn from curriculum materials designed to promote teacher learning as their main professional development support during a school year. The two teachers in this study diverged greatly in what they learned from the materials. Moreover, they constructed very different opportunities to learn through enacting and reading the materials. The analysis suggests that to fully understand a teacher's dynamic construction of opportunities to learn, the beliefs that constitute the teacher's identity need to be considered in relation to the beliefs that are targets of change through professional development.

Several additional issues are worthy of investigation. First, how curriculum materials themselves might embody a pedagogical design that facilitates use of the content for teachers merits attention. Second, future studies could consider how context variables such as different types of students, grade levels, and subjects, and kinds of collegial and organizational support affect teachers' construction of opportunities to learn. Finally, because teacher learning develops over time, future research could investigate how and what teachers learn through cur-

riculum materials changes across subsequent years.

## Note

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